ONTARIO

DEPARTMENT OF MINES

GRAPHITE IN ONTARIO

By

D. F. HEWITT

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GRAPHITE IN ONTARIO

By

D. F. Hewitt[1]

INTRODUCTION

The mineral graphite is a form of carbon crystallizing in the hexagonal system. It is black to silver-grey in colour, very soft and unctuous, with a metallic lustre and black streak. Its hardness is 1 to 2. It usually occurs in flakes which are flexible and sectile, and exhibit perfect flaky basal cleavage. The specific gravity is 2.1. Graphite is a good conductor of heat and electricity but is extremely resistant to acids and heat. It is chemically inert and highly refractory, melting at 3500°C. and vapourizing at 4500°C. Graphite is used for insulating rods in atomic piles to absorb radiation and control the rate of reaction in the pile.

Diamond and charcoal are other forms of natural carbon which, although chemically similar, exhibit vastly different properties than graphite.

Graphite is classified as crystalline flake or amorphous graphite depending on its particle size. Amorphous graphite can be produced from crystalline flake by grinding. Amorphous graphite is not visibly crystalline, being extremely fine-grained.

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[1]Senior Geologist, Industrial Minerals, Ontario Department of Mines, Toronto.

Amorphous graphite of high chemical purity is manufactured by an electric furnace process. This so-called "artificial" or manufactured graphite is competitive with amorphous graphite.

Commercial graphite grades from 70 - 99 percent carbon. The less pure varieties carry varying amounts of associated minerals such as quartz, feldspar, mica, and carbonate.

The most common type of graphite found in Ontario is flake graphite. It occurs disseminated in marble and paragneiss and is most commonly found in the Grenville geological province of eastern Ontario.

Graphite was produced commercially in Ontario from 1896 to 1954. Total Ontario graphite production during this period amounted to 95,156 tons valued at $6,114,768. The peak production year was 1950 when 3,586 tons of graphite valued at $390,815 were produced.

Graphite is used for crucibles, refractory ware, lubricants, carbon brushes, foundry facings, batteries and lead pencils.

Mode of Occurrence

The graphite deposits of Ontario are of four types:

(1) Disseminated graphite in paragneiss;

(2) Disseminated graphite in marble;

(3) Contact metamorphism or metasomatic graphite in marble;

(4) Graphite in pegmatites.

Attempts have been made to commercially exploit all four types of deposits in Ontario; the Black Donald mine, a long-time producer, was of type (3).

Ontario Graphite Production

Ontario graphite production from 1896 to 1954 amounted to 95,156 tons valued at $6,114,768. Annual Ontario graphite production for this period was as follows:

Year	Tons	Value	Year	Tons	Value
1896	650	$ 13,000	1926	2,266	$ 158,994
1897	400	8,500	1927	1,795	109,613
1898	300	6,000	1928	1,047	52,373
1899	1,220	16,179	1929	1,288	90,522
1900	1,802	27,030	1930	1,338	86,543
1901	1,000	20,000	1931	548	32,149
1902	1,923	17,868	1932	346	18,483
1903	4,400	20,636	1933	362	16,145
1904	355	4,700	1934	1,389	64,998
1905	2,078	9,825	1935	1,761	78,500
1906	1,772	15,000	1936	2,045	88,812
1907	2,000	20,000	1937	2,511	125,343
1908	10	1,600	1938	723	41,590
1909	730	37,624	1939	1,101	61,684
1910	992	55,637	1940	1,382	94,038
1911	894	36,492	1941	1,644	132,924
1912	1,246	65,076	1942	1,192	117,904
1913	1,788	93,054	1943	1,903	197,431
1914	1,363	87,167	1944	1,582	171,166
1915	2,534	115,274	1945	1,910	179,001
1916	3,476	249,586	1946	1,975	180,405
1917	3,173	220,018	1947	2,398	207,364
1918	1,894	162,048	1948	2,539	239,931
1919	1,340	99,821	1949	2,147	212,496
1920	1,956	132,882	1950	3,586	390,815
1921	363	23,273	1951	1,569	231,167
1922	626	34,124	1952	2,040	255,732
1923	1,068	65,557	1953	3,466	366,528
1924	1,288	72,842	1954	2,452	253,441
1925	2,210	127,863			
				95,156	$6,114,768

Grades of Graphite Products

Throughout its history the Black Donald mine produced a great range of graphite products. In 1949 the distribution of products was approximately as follows: 11.6 percent flake; 30.8 percent flake dust; 55.7 percent amorphous and 1.9 percent smoke. In 1954 when the mine closed more than 40 different graphite products were being produced.

Andersen (1954, pp. 685-6) describes the refining of graphite at the Black Donald as follows: "After the concentrate has been dried in the rotary oil-fired kiln, the ultra-fine portion is removed by two dust collectors. The dust products, which are slightly oily, are used by the paint industry. The graphite is then carried by bucket elevators to a storage tank from which it is fed to two grinding stones. Here the soft but tough graphite flakes are flattened out while the hard and brittle quartz particles disintegrate under the grinding action. From the stones, the graphite goes to four bolting screens, using 80 mesh silk cloth, where the flake is separated from the amorphous type. The latter is split on subsequent bolting screens into three standard products according to particle size. The flake portion, assaying 95 percent C , is subjected to a second grinding operation where the carbon concentrate of the coarse flakes is brought up to 97 to 98 percent. The flake is then split on a bolting screen into a plus 50 mesh and a plus 80 mesh product. These grades are used almost exclusively as lubrication. The fines from the flake stone are subdivided into several products which are used in the foundry-facing

field and for making lower-priced lubricants. From time to time it is necessary to supply material to narrow size limits. This sizing is performed on specially designed screening devices, such as a gyro-whip."

"There is a great demand for finely ground graphite, screening 90 percent minus 325 mesh. To obtain this product, raw graphite is fed to two dry-grinding units consisting of two ball mills. Here the graphite is pulverized and pulled off by dust collectors. Recently an air skimmer was installed in the dust circuit in order to reduce the plus 325 portion in the finished product. The present set-up of screens and dry grinding equipment permits us to manufacture graphite to almost any specification."

Graphite Exports and Imports

Graphite exports and imports into Canada as reported by the Dominion Bureau of Statistics are as follows:

	Exports	Imports		
Year	Natural graphite (Short tons)	Unmanufactured	Crucibles	Ground and Manufactured
1951	1152	$96,725	$215,297	$476,511
1952	1686	97,658	213,429	434,650
1953	3253	125,740	217,066	481,982
1954	2156	54,385	156,516	548,824
1955		64,798	202,864	561,394
1956		87,926	260,000	815,384
1957		74,089	237,333	748,732
1958		53,219	166,056	909,226
1959		64,014	224,204	976,250
1960		75,714	236,148	905,756
1961		47,450	215,788	945,258
1962		58,351	254,447	1,362,492
1963	(preliminary)	86,991	284,206	2,353,816

Amorphous graphite is produced by Mexico, Korea and Austria. A large percentage of crucible flake comes from the Malagasy Republic (Madagascar). Ceylon, West Germany and Norway are also producers.

Graphite Prices

Graphite prices are quite variable depending on the grade and type of graphite purchased. Prices of Black Donald graphite ranged from 4¢ per pound for lower grades of amorphous graphite to 13¢ per pound for large flake.

Prices quoted by E. & M. J. Metal and Mineral Markets, August 31, 1964 were as follows: Flake and crystalline graphite, f. o. b. source, bagged, per metric ton:

Madagascar	$90-200
Norway	$80-140
Germany	$114-672
Ceylon	$95-250

Amorphous non-flake, f. o. b. source, 80-85 percent carbon:

Mexico, bulk, metric ton,	$17-20
Korea, bulk, metric ton,	$15
Hong Kong, bagged, long ton	$21

USES AND SPECIFICATIONS

Flake graphite is used principally for crucibles, refractory ware, lubricants, batteries and to some extent in foundry facings. Amorphous graphite is used mainly for

foundry facings, batteries, paint and pencils (Cameron and Weis, 1960).

Crucibles and Refractory Ware

For the manufacture of graphite crucibles, stoppers, covers, nozzles, retorts and other refractory ware, flake graphite of large size (20 to 90 mesh) is used. Carbon content is generally high, being over 85 percent C. Mica, calcite, pyrite and pyrrhotite are undesirable impurities (Cameron and Weis, 1960, p. 216).

Lubricants

Flake graphite having a high carbon content (usually over 95 percent) and freedom from abrasive impurities such as quartz and feldspar, is used for lubricants. Graphite is also used in packings and bearings due to its lubricating qualities.

Brushes

Graphite of high purity (97 to 98 percent C) and free from abrasive impurities is desirable for the manufacture of carbon brushes for electric motors.

Foundry Facings

One of the largest consumers of graphite is the foundry industry. Small flake and amorphous graphite of lower carbon content (40 to 80 percent) are used for this purpose and mineral impurities can be tolerated.

Batteries

Amorphous, flake or manufactured graphite is used in the manufacture of dry batteries. Minimum carbon content is 85 percent, and metallic oxides or sulphides are objectionable. Graphite has been replaced to some extent for this use by acetylene black (Cameron and Weis, 1960, p. 222).

Pencils

Amorphous and finely ground flake graphite are mixed with clay to produce lead pencils. Carbon content of at least 85 percent is desirable.

Paints

Graphite is used as a pigment in some anti-corrosive paints. Amorphous smoke graphite is used for this purpose and carbon content is variable.

Steelmaking

Low cost amorphous graphite is used in recarburizing steel. Other forms of carbon are also suitable for this purpose.

Minor Uses

Minor uses include stove and shoe polish, filler in fertilizers, coating tea leaves and coffee beans, roofing compounds, rubber goods and coatings for television tubes.

Manufactured Graphite

Manufactured graphite is used for manufacture of graphite electrodes for the metallurgical and chemical industries. It is also used as a moderator in atomic piles.

MILLING GRAPHITE

Mill circuits for the recovery of flake and amorphous graphite vary considerably depending on the grade and character of the ore and gangue. At Black Donald mine the ore was crushed to one inch size, ground in a ball mill in closed circuit with a classifier, and floated. The rougher concentrate is screened with the plus 40 mesh material going to a filter and drier. The minus 40 mesh material is cleaned further by flotation, the tailings being reground and recirculated. Final cleaning is by Callow cell. The concentrates are dried.

Refining is done by grinding stones and screens. A further description of the Black Donald mill is given under the property description.

A discussion of graphite milling is given by Cameron (1960, p. 464). Commonly the ore is crushed, ground and floated, with successive stages of flotation to upgrade the concentrates. Refining is by regrinding and dry screening. In Madagascar ores running 4 to 10 percent C are upgraded to 85 percent C by crushing, grinding, flotation and screening. Similar circuits are used in Bavaria, Norway and the United States.

GRADE OR TENOR OF ORE

The grade of a graphite deposit which can be profitably worked depends on the size and percentage of flake in the milled product. A mill test is essential before an evaluation of a graphite deposit can be made. Graphite deposits grading as low as 4 percent are reported to have been worked commercially (Cameron 1960, p. 464). The tenor of commercial deposits in Ontario would probably range from 8 to 15 percent. Since the price of graphite ranges from 4 to 13¢ per pound depending on size and carbon content, the value of graphite ore will obviously depend on the percentage recovery of the larger sizes of flake as well as the carbon content of the ore.

DESCRIPTION OF PROPERTIES

Frontenac County

Bedford Township
Concessions IV and V, Lot 4
Kirkham Graphite Property [1]

During the closing stages of operation at the Black Donald mine, Frobisher Limited carried out a careful examination of several other graphite deposits in Ontario and Quebec. A substantial graphite orebody was outlined at the Kirkham Graphite property in Bedford township, Frontenac county, Ontario, about 5 miles east of Godfrey.

In 1952, 30 diamond-drillholes, totalling 9,860 feet, were drilled and two lenses of graphite ore outlined. The eastern lens outcrops on the shore of Desert Lake, and was stripped for a length of a hundred feet. A 300-ton bulk sample was shipped to the Black Donald mine for milling. In 1953, an electromagnetic survey indicated a potential mineralized zone over 4,000 feet long.

The diamond-drilling outlined two parallel lenses of graphite ore, as shown in the plan and sections, figure 3.

---

[1] Plan, sections and description of this property are based on a company report by B.G. Edward, Manager of the Black Donald Graphite project, Frobisher Limited.

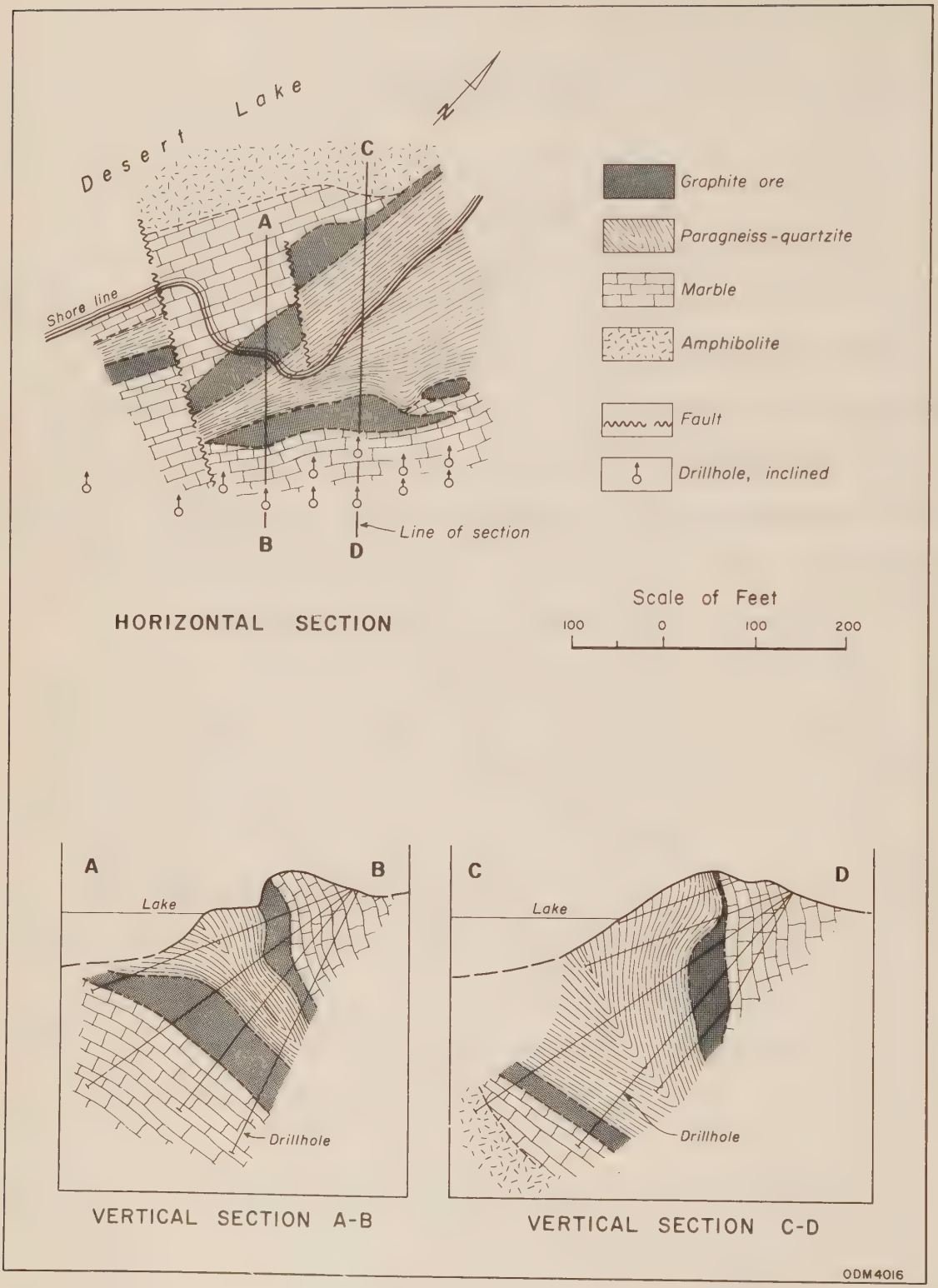

Figure 1. Plan and diamond drill sections of Kirkham graphite property Frontenac county. Courtesy of Frobisher Limited.

These ore lenses occur on the east and west limbs of a syncline plunging to the north-northeast. The east or upper zone has a length of about 300 feet, a maximum width of 22 feet, and is estimated to contain proven ore reserves of 86,000 tons, running 10 percent carbon. The lower or western zone has a length of about 250 feet, and pinches out to the north. At the south end it is thought to be terminated by a fault, and a second fault 150 feet to the north apparently offsets the ore zone on this limb of the fold. This ore zone has a maximum width of about 25 feet and contains proven ore reserves of 120,000 tons grading 12 percent carbon. The graphite is flaky and occurs disseminated in a silicated marble. Mill tests indicate that the product consists of some 20-50 mesh flake and a large volume of plus 80 mesh flake. The ore is easily milled and recovered. The flake is of good body and high density, and is tough and resistant to attrition during milling.

The graphite deposit is located at the northeast end of Desert Lake within the Grenville Series just south of a large mass of granite gneiss which forms the range of hills northwest of Desert and Canoe Lakes. As shown on the accompanying plan and diamond-drill sections, the graphite occurs in a synclinal structure in the Grenville marble - paragneiss - quartzite sequence. The syncline plunges northeast at 25° and is overturned to the west so that the west arm dips eastward at about 45°, and the overturned east arm dips eastward at about 70°. The graphite flake occurs in a

highly silicated marble at the contact with the overlying siliceous paragneiss and quartzite. Pyritic quartzite and paragneiss forms the centre of the syncline which is underlain by silicated marble. The graphite ore zone occurs in marble at the quartzite - marble contact of both arms of the syncline. The Grenville rocks are cut by pegmatite dikes.

Metasomatic alteration by solutions has altered the marble along the quartzite contact to a granular aggregate of diopside, serpentine, carbonate and graphite. Some post-ore shearing has occurred. Granite pegmatite stringers are common. The orebody is classed as metasomatic replacement type; the graphite zones lie in the marble a few hundred feet from the main granite contact.

Concession V, Lot 1

Harding (1951, p. 62) reports that "A pit about 15 feet deep has been sunk on a graphite showing on the side of a hill facing Birch Lake on lot 1, concession V, Bedford township. The excavation lies in vertically dipping Grenville crystalline limestones which strike approximately N.80°E. Graphite is disseminated in the limestone on the north wall of the pit in a band that ranges in width from 1 to 8 inches. Some sections of this band contain sufficient graphite to make the rock almost black in appearance. No substantial body of graphite-bearing rock of commercial grade was exposed in the pit."

Concession VI, Lot 2

Bawden Mine

Harding (1951, p. 62) reports that "During the latter part of the last century a shaft was sunk to a depth of about 30 feet, and a few feet of drifting was done on a graphite showing close to the northwest shore of Birch Lake on lot 2, concession VI, Bedford township. The work was carried out by Joseph Bawden, of Kingston. A report by the Royal Commission published in 1890 states that 100 barrels of graphite ore were produced and shipped to the United States. The graphite occurs in flakes disseminated in beds of Grenville crystalline limestone. The deposit is not of the fissure-vein type. The limestones in the vicinity are steeply folded and strike in a northeasterly direction parallel to the shore of Birch lake. "

Concession VIII, Lot 18

Graphite occurs disseminated in white Grenville marble on lot 18, concession VIII, Bedford township on the property of George Butterill of Fermoy. A few shallow pits have been put down (Harding, 1951, p. 62).

Kennebec Township

Concession VI, Lot 8

Harding (1944, p. 74) describes a graphite showing on lot 8, concession VI, Kennebec township about 15 chains east of the Arden - Tamworth road. A graphite-bearing pegmatite cuts paragneiss which also carried graphite. Three pits were put down on the pegmatite dike.

Oso Township

Concession I, Lot 3, East Half

Disseminated graphite in Grenville marble, pegmatite and granite was reported on the east half of lot 3, concession I, Oso township by W. D. Harding (1951, p. 61).

Concession IV, Lot 19

Harding (1951, p. 61) reports an occurrence of graphite in small veins in hornblendite on lot 19, concession IV, Oso township. Two pits about 8 feet deep and 25 feet apart were sunk about 300 feet from the southwest corner of this lot. The hornblendite intrudes Precambrian metasediments.

HALIBURTON COUNTY

Cardiff Township

Concession XIV, Lot 18

On the top of a hill, 350 feet southeast of Cup Lake, there is a graphite prospect pit measuring 15 by 15 by 10 feet deep. This pit is reported to have been sunk in 1909 by R. Dickson and A. Riddell. Graphite flake up to 3/16 inch in size occurs in rusty-weathering biotite amphibolite. The graphite zone exposed in the old pit is about 2 feet wide and is estimated by the author to average 10 percent graphite. The band strikes east-west and dips 45°S.

Associated with the graphitic gneiss are biotite syenite gneiss, biotite paragneiss, and metamorphic pyroxenite. Finely disseminated pyrrhotite and molybdenite occurs in rusty-weathering bands adjacent to the graphitic zone.

Concession XV, Lot 18

There is a small band of graphitic paragneiss exposed on the north side of the creek joining the two parts of Cup Lake. The feldspathic paragneiss band strikes N.80°W. and dips 50°S. A small open cut with a 4-foot face has been blasted in the south dip face of the graphitic band. The graphite occurs in flakes 1/8 - $\frac{1}{4}$ inch in size disseminated through a 4-foot band in the paragneiss. The author

estimates that the graphite content runs 8-10 percent over the 4-foot width. To the north the paragneiss is underlain by pink leucosyenite and granite gneiss. To the south it is overlain by granite gneiss. A small pit just south of the creek exposes rusty paragneiss with a few large flakes of graphite.

Concession XIX, Lot A

Near the west boundary of the south half of lot A, concession XIX, Cardiff township, there is a small prospect pit 12 by 10 by 8 feet deep in coarsely crystalline white marble. Flake graphite up to $\frac{1}{2}$ inch in size occurs in rich seams 8-10 inches wide in an ore zone 3 feet thick. The graphite zone was estimated to average about 25 percent over a 3-foot width. The rock is not exposed around the pit, and no estimate of the length or size of the deposit could be made.

Concession XX, Lot A

There are four graphite prospects in lot A, concession XX, Cardiff township. Near the west boundary of the lot, 3/4 mile south of the railway, there are two prospect pits, one 20 by 10 by 8 feet deep, the other 10 by 8 by 6 feet deep. The pits are in white crystalline limestone carrying 2-3 percent flake graphite. There is another small prospect pit in graphitic marble near the south boundary of the lot, 600 feet west of a small lake.

About 100 feet west of the small lake there is an open cut 25 feet long, 5 feet wide, and 5 feet deep in pink leucosyenite

near the marble-syenite contact. The leucosyenite carries 1-2 percent graphite flake up to $\frac{1}{4}$ inch in size.

About 1,000 feet northwest of the small lake there is an old inclined shaft near the top of a small hill. The shaft is 20 feet wide, 10 feet high, and at least 80 feet deep. It runs south-southeast at an incline of 25 degrees, parallel to the dip of the marble in which it occurs. The marble carries 5-8 percent graphite flake up to $\frac{1}{4}$ inch in size.

Concession XXI, Lot 1

In lot 1, concession XXI, Cardiff township, about 800 feet east of Pusey Lake, near the centre of a large marble outcrop area, there is a small pit in graphitic marble. The percentage of flake graphite is small, not exceeding 2 percent. The marble contains chondrodite.

Concession XXII, Lot 4

An old pit measuring 6 by 3 feet deep, occurs in lot 4, concession XXII, Cardiff township, 350 feet south of Lower Cardiff Lake between the road and railway. White crystalline limestone carrying less than 5 percent graphite is exposed in the pit.

Concession XXII, Lot 11

National Graphite Property

A graphite prospect in lot 11, concession XXII, Cardiff township, was opened up by New York Graphite Company in 1912. This company sunk a number of test pits and did some diamond-drilling along the north slope of the hill facing the railway. The largest opening was an open pit 40 feet deep, 60 feet long, and 15 feet wide. The company built a mill and operated intermittently until 1915 when it was merged with National Graphite Company. Mining was discontinued, and the mill operated in 1915 and 1916 on ore from Monteagle township, Hastings county.

During 1951, Black Donald Division of Frobisher Limited, drilled the property under the supervision of B. G. Edward. A graphite-bearing zone 1,200 feet long and 60 feet thick was disclosed by 4,270 feet of diamond-drilling. An orebody of 1,440,000 tons grading 4.1 percent carbon was indicated. Within this orebody there is a richer zone of 800,000 tons grading 5 percent carbon.

The flake graphite, up to 1/8 inch in size, occurs in limy paragneiss, which strikes N.30°E. and dips 15°S. Some pyrite accompanied the graphite.

Concession XXII, Lot 24

A small occurrence of graphite-bearing syenite pegmatite was opened up in lot 24, concession XXII, Cardiff township, in 1942 by B. E. MacDougall. Two small pits located about 3/8 mile north of the road expose a 3-foot dike of brown-weathering syenite pegmatite carrying 5-20 percent coarse flake graphite up to 3/4 inch in size. The pegmatite occurs at the contact of marble and paragneiss.

Monmouth Township

Concession XIII, Lot 32

A graphite occurrence is described by Satterly (1943a, p. 41) in lot 32, concession XIII, Monmouth township. An open cut 20 by 15 feet by 10 feet deep exposes impure white to grey crystalline limestone carrying $\frac{1}{2}$ to one percent graphite in flakes averaging 1/20 of an inch in diameter. Locally the graphite content reaches 10 percent. Pegmatite stringers cutting the marble also carry graphite flakes.

Concession XIV, Lot 35, North Half

Another occurrence of graphitic marble was examined by Satterly (1943a, p. 42) in the north half of lot 35, concession XIV, Monmouth township. Two small pits expose

graphite-bearing marble with a spotty distribution of graphite.

Concession XIV, Lot 35, South Half

T. Morrison opened a graphite prospect on the south half of lot 35, concession XIV, Monmouth township. No workings are reported on the property (Satterly 1943a, p. 42). A graphitic zone was traced by outcrop and float but further exploration would be needed to evaluate the deposit.

Concession XV, Lot 35, South Half

Two pits measuring 40 by 25 by 20 feet deep and 25 by 20 by 7 feet deep were put down on graphiticmarble in the south half of lot 35, concession XV, Monmouth township (Satterly 1943a, p. 42). Disseminated graphite flakes averaging 1/8 inch in size occur in bands and seams in the marble. Only a small percentage of the marble grades 10 percent graphite.

Concession XVI, Lots 34 and 35

An inclined adit has been driven into the side of a hill on lot 34, concession XVI, Monmouth township. The rock is marble interbedded with paragneiss. Disseminated graphite is present in the marble in percentages up to 10 percent (Satterly 1943a, p. 42). Spence (1920, p. 27) reports that the adit was 8 by 15 feet and 100 feet long.

Four pits are located on lot 35, concession XVI. The largest measures 40 by 75 feet and about 100 feet deep (Spence 1920, p. 27). Graphite occurs disseminated in marble. There is no well-defined ore zone and Spence states that the ore is comparatively low grade probably averaging about 5 percent.

The property was operated by the Virginia Graphite Company from 1910 to 1913, and in 1914 by the Tonkin-Dupont Graphite Company Limited. The mill was closed in May 1914 (Satterly 1943a, p. 42).

HASTINGS COUNTY

Carlow Township

Concession VIII, Lot 10

The graphite prospect pit on lot 10, concession VIII, Carlow township, is located 1,200 feet north-northwest of a small cabin on the southwest shore of McWhirter (Stoney) Lake. The prospect pit is on the west side near the top of the hill just west of the lake. The pit measures 12 by 15 feet and is 6 feet deep down to water level.

The rocks exposed in the pit are interbanded amphibolite and crystalline limestone cut by granite pegmatite. The crystalline limestone is pure, containing a few scattered flakes of phlogopite and no graphite. Graphite, in fine flakes up to 1/8 inch in diameter and in fine seams, lenses,

and patches, occurs disseminated in the amphibolite. Some samples from the dump contain considerable fine graphite; material exposed in the pit is of poor quality and grade.

Faraday Township

Concession I, Lot 12

An occurrence of fine-grained graphite has been reported by Thomson (1943,p. 34) in a test pit on lot 12, concession I, Faraday township. The graphite occurs as a network of veinlets in a zone 1 to 2.5 feet in width and only a few feet in length.

Herschel Township

Concession VIII, Lot 16, South Half

Thomson (1943, p. 34) reports that: "A claim in the south half of lot 16, concession VIII, Herschel township, was staked for flake graphite by John McAllister in 1911 and a few shallow pits were opened. The showing consists of two parallel bands of graphitic gneiss, about 4 feet in thickness and 50 feet apart. One band may be traced about 50 feet. The graphite occurs in an area of mixed pegmatite, limestone, and leached gneiss. The graphite content is fairly low; the flake is from a quarter to a third of an inch in diameter."

Concession X, Lot 24, North Half
Concession XI, Lots 24 and 25

Several shallow test pits were put down in 1912 and 1913 in the north half of lot 24, concession X and lots 24 and 25, concession XI, Herschel township, in graphite-bearing granitic gneiss (Thomson 1943, p. 34). Samples taken by Thomson assayed 5.3 and 6.4 percent graphite.

Concession XI, Lots 17 and 18

Six test pits have been put down in rusty-weathering graphite gneiss on lots 17 and 18, concession XI, Herschel township (Thomson 1943, p. 34-5). Thomson estimated the graphite content at 2 to 4 percent.

Monteagle Township

Concession V, Lot 16

There is a small showing of graphite on lot 16, concession V, Monteagle township, just north of a small lake on the south half of the lot. Flake graphite up to $\frac{1}{4}$ inch occurs in crystalline limestone that is intruded by granite gneiss and pegmatite. There is one small test pit. A grab sample of graphitic limestone, taken by J. E. Thomson, ran 1.97 percent graphite (Thomson 1943, p. 35).

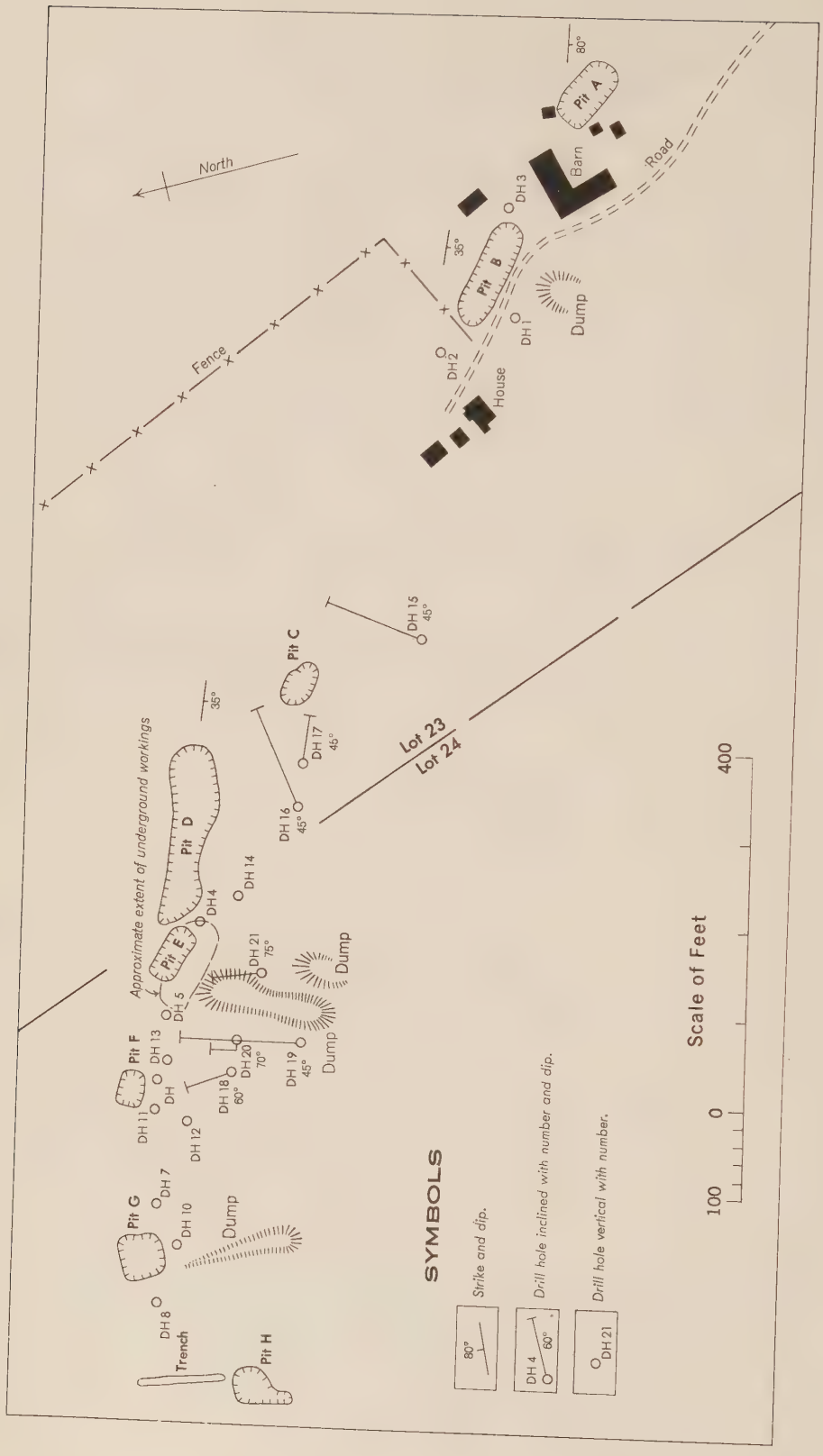

Figure 2. Sketch map of the Tonkin-Dupont and National Graphite workings, Monteagle township, Hastings county.

Concession XIII, Lot 23 (Tonkin-Dupont Mine)
Concession XIII, Lot 24 (National Graphite Mine)

The Tonkin-Dupont Graphite Company of New York began mining on lot 23, concession XIII, Monteagle township, in 1912. The property is situated ½ mile east of Graphite station on the Canadian National railway. In 1913 this company produced 198 tons of refined graphite, valued at $19,800, and, in 1914, 240 tons, valued at $28,800, from their graphite mill located at Wilberforce. The bulk of the ore treated at the Wilberforce mill during these years came from the Monteagle township deposit.

In 1915 the National Graphite Company opened a mine on lot 24 on the continuation of the Tonkin-Dupont orebody and shipped 2,000 tons of ore to a mill at Mumford station, Haliburton county. From this ore, 44½ tons of graphite, valued at $6,611.84 was recovered. In 1916, 6,300 tons of ore was shipped, and 310 tons of graphite, valued at $50,840, was produced.

These properties have been inactive since 1917. In 1942 S. H. Law of Toronto held the mineral rights on both properties, and some investigations were carried out. In 1952 S. H. Law and McKenzie Red Lake Gold Mines did 1,100 feet of diamond-drilling on these properties, and in 1953 the main workings on lot 24 were dewatered and sampled.

In July and September 1962, Canada Graphite Mines Limited did 2,300 feet of diamond-drilling on the properties.

The graphite flake occurs in crystalline limestone,

green metapyroxenite, rusty paragneiss, amphibolite, granite gneiss and pegmatite. The graphite occurs in flakes ranging from 1/16 to $\frac{1}{4}$ inch in size. The best ore sections run 15-20 percent graphite. The grade was reported as about 7 percent by Spence (1920, p. 26). Phlogopite and molybdenite occur with the graphite. Diopside, epidote, tremolite, scapolite, garnet, magnetite, pyrrhotite, titanite, and apatite occur in the lime silicate skarn.

The location of workings and diamond-drillholes are shown on the accompanying map. On lot 23 there are four pits. Pit A, located southeast of the barn, is 80 by 40 by 25 feet deep. The graphite occurs in crystalline limestone in flakes up to 3/16 inch in diameter. Rusty paragneiss occurs interbedded with the crystalline limestone. The rocks strike N. 45°W. and dip 80°S.W. A chip sample, taken across 13.5 feet on the north side of the pit by J. E. Thomson (Thomson 1943, p. 36) assayed 12.6 percent graphite. There is some phlogopite with the graphite.

Pit B, located just northwest of the barn, is 120 feet long, 35 feet wide, and 10 feet deep to water level. The northeast wall is crystalline limestone with graphite flakes up to 1/8 inch in size. The southwest wall of the pit is rusty paragneiss and amphibolite. The rocks strike N.65°W. and dip 35°S.W. A chip sample across a 16-foot width of graphitic crystalline limestone taken by J. E. Thomson contained 10.37 percent graphite (Thomson 1943, p. 36).

Pit C, located 300 feet northwest of the farmhouse, is

30 by 40 by 15 feet deep. The rocks exposed are silicated crystalline limestone, rusty paragneiss, and amphibolite. The main pit on the Tonkin-Dupont property is Pit D, an open cut 200 feet long and 15-40 feet wide trending N.75° W. parallel to the strike of the limestone and paragneiss. The formations dip about 35°S.W., and the open cut follows the formation down dip. Spence (1920, p.28) reports that this pit has a depth of 75 feet. The rocks exposed are silicated crystalline limestone containing phlogopite and graphite, rusty paragneiss, and amphibolite and grey granular diopside rock.

There are four pits on lot 24 on the former National Graphite property. Pit E, which is the main pit on the property, is 60 by 30 feet at the surface. The pit was dewatered in 1953 and consists of a large open stope, 150 feet deep, dipping about 70°W. At the 150-foot level the opening is 150 feet long in a northwesterly direction and 20-40 feet wide. There are two benches at the northwest end of the stope. The rocks exposed consist of graphitic crystalline limestone, lime metapyroxenite, rusty paragneiss and amphibolite, and some granite pegmatite. Within the stope there is considerable folding, and the bedding is not well marked. The width of the graphite-bearing horizon that was mined is difficult to determine since it is not well exposed in the walls. Some graphite ore occurs on the southwest wall.

Pit F, measuring 20 by 30 by 20 feet deep, exposes interbedded crystalline limestone, silicated limestone, lime

silicate rock, and paragneiss. Pit G measures 40 by 40 feet and is about 10 feet deep. The rocks exposed are rusty paragneiss, metapyroxenite, and silicated limestone. A little graphite occurs in pits F and G. Pit H is a stripping 20 by 30 by 7 feet deep. No graphite was observed.

The best graphite section cut in diamond-drilling in 1952 was in hole No. 13 where an ore intersection between 89 and 105 feet was estimated by the writer to run 15-20 percent, 1/8-$\frac{1}{4}$ inch, graphite flake. Other narrower sections were cut in other holes, and at least two graphite-bearing horizons are indicated.

Concession XIV, Lot 13 and 14

A 10-foot wide graphite-bearing band of paragneiss is exposed on these lots on the property of Sam Robinson of Greenview. The graphite zone is exposed on the hillside just east of the road. The paragneiss strikes N.40°W. and dips 25°N.E. It is underlain by crystalline limestone. The graphite zone can be traced for over 300 feet on surface and is best exposed in a small open cut 12 by 8 feet in the side of the hill. The graphite occurs in flakes up to 3/8 inches in diameter, averaging 1/8 inch. The adjacent paragneisses to the east carry disseminated graphite flakes over a width of 40 feet. An analysis of a channel sample, taken by J. E. Thomson (Thomson, 1943, p. 37) across the 10-foot width of the graphite zone exposed in the pit, indicated 2.97 percent

graphite (Thomson 1943, p. 37). The graphite is in a medium-grained quartzo-feldspathic paragneiss that weathers to a rusty-brown colour.

Tudor Township

Concession IX, Lot 21

Veins and pockets of amorphous graphite are reported to occur in Grenville marble in lot 21, concession IX, Tudor township.

LANARK COUNTY

North Burgess Township

Concession V, Lots 24-26

Timmins Mine

The Timmins graphite mine, operated in 1918 and 1919, is located on lots 24 to 26, concession V, North Burgess township, 14 miles southwest of Perth and 7 miles from Westport.

The graphite occurs as disseminated flake in white silicated marble. Common impurities are calcite, pyroxene, mica and pyrite. Interbanded with the marble are bands of paragneiss. Granite and granite pegmatites cut the marble and these intrusions are especially common on lot 26. Graphite flakes of medium to large size occur in the marble with richer concentrations on shear zones or near the granite

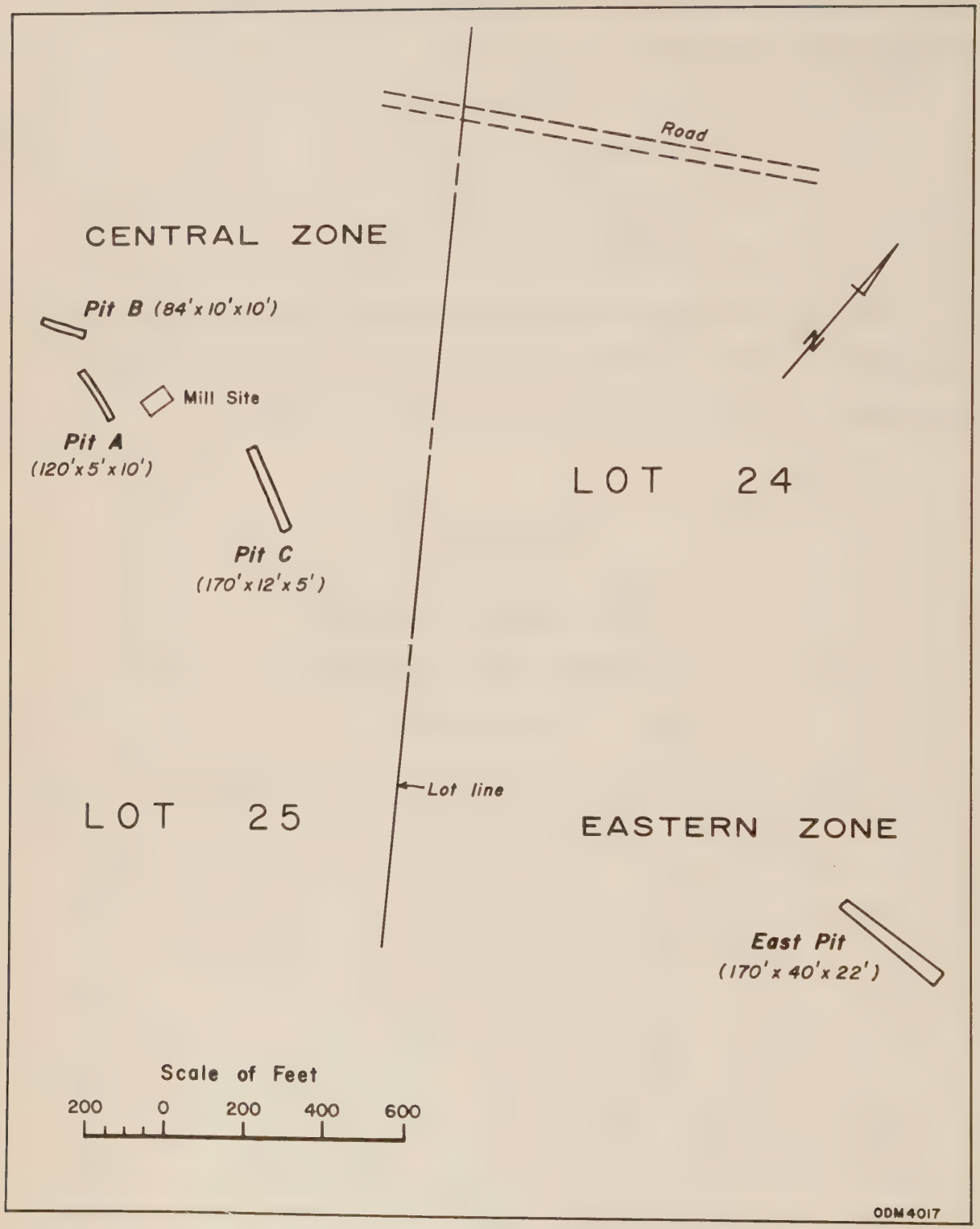

Figure 3. Timmins graphite property, North Burgess township, Lanark county.

intrusions.

There was no underground development on the property, all workings were open pits. The accompanying sketch map is a plan of the property showing the main workings. On lot 25 where the mill was located there are three pits. Pit A is 100 feet southwest of the mill site. It has a length of 120 feet, a depth of 10 feet, and a width of 5 feet. Pit B located 250 feet west of the mill site is 84 feet long, 10 feet wide, and 10 feet deep. Pit C, located 300 feet east of the mill site, is 170 feet long, 12 feet wide and 5 feet deep. These pits on lot 25 apparently supplied ore for the mill.

On lot 24, 2,400 feet east of the mill site an eastern graphite zone was located. A pit 170 feet long, 40 feet wide, and 22 feet deep was excavated and an estimated 11,000 tons of graphite ore remains on the dump at this pit.

In 1951 the Timmins property was drilled by Frobisher Limited, and a mill test was carried out on 150 tons of ore trucked to the Black Donald mill in January 1951. Five diamond-drillholes were put down at 100-foot intervals on the eastern zone, lot 24. Drilling outlined a lens of graphite ore striking N.70°E. over a length of 300 feet. The average width was 11.1 feet and average grade 7.6 percent carbon, equivalent to an indicated tonnage of 55,000 tons of 7.6 percent ore to a depth of 200 feet.

On the central ore zone in lot 25 the graphite zone was drilled off by 15 holes on 50-foot intervals with 2 holes drilled on four of the sections. A graphite zone was indicated with a length of 450 feet grading 8.4 percent carbon over an average width of 12.7 feet. Drilling indicated both the central and eastern zones pinched out along strike and no continuity between the zones could be proven. Total footage of drilling was 4,040 feet.

Mill tests at the Black Donald mine indicated that due to the presence of very thin mica plates intergrown with the graphite it was found impossible to produce high carbon flake in the large sizes. Carbon content in the large sizes ranged from 90 to 94 percent C which is too low to find substantial markets. Commercially acceptable products were produced in the small flake and amorphous grades. These products were of rather light body.

In the preliminary mill test, mill heads assayed 9.6 percent C, tails 2.5 percent C, and concentrate 73 percent C. Primary grind alone was not sufficient to free the graphite from the gangue so that the cleaner cells and regrind circuit were cut in. The preliminary split between flake and amorphous products was made on a No. 14 cloth. Products from the flake circuit ran special (plus 50 mesh), 90.3 percent C ; No. 1 (plus 80 mesh), 89.5 percent C ; No. 2 (plus 120 mesh), 92.3 percent C ; No. 3 (plus 200 mesh), 79.2 percent C ; No. 44 (minus 200 mesh), 45.1 percent C.

Since additional grinding did not improve the carbon content of any grade appreciably, the No. 14 cloth was

replaced by No. 10 cloth and the additional middling was dropped on the amorphous side. This split increased the grade as follows: special, 95.1 percent C ; No. 1, 94.1 percent C ; No. 2, 94.5 percent C ; No. 3, 88 percent C ; No. 44, 50 percent C; flake concentrate, 85.5 percent C. Interlaminated mica held down the carbon content of the flake, and grades comparable to that of the Black Donald ore were not obtained. The flake dusts and amorphous grades in the low carbon ranges are dry and not particularly desirable for foundry use. The dust products gain visibly in unctuousness with increased carbon content but are not equal to the Black Donald product in this respect.

The foregoing description of exploration and mill testing of the Timmins ore was abstracted from a report by B. G. Edward, manager of the Black Donald mine, with permission of Frobisher Limited.

North Elmsley Township
Concession VI, Lots 21 and 22
Globe Graphite Mine

The Globe graphite mine is in lots 21 and 22, concession VI, North Elmsley township, six miles southeast of Perth on the road from Perth to Rideau Ferry.

The mine was opened in 1870 by the International Mining Company of New York and worked until 1875. In 1893 the

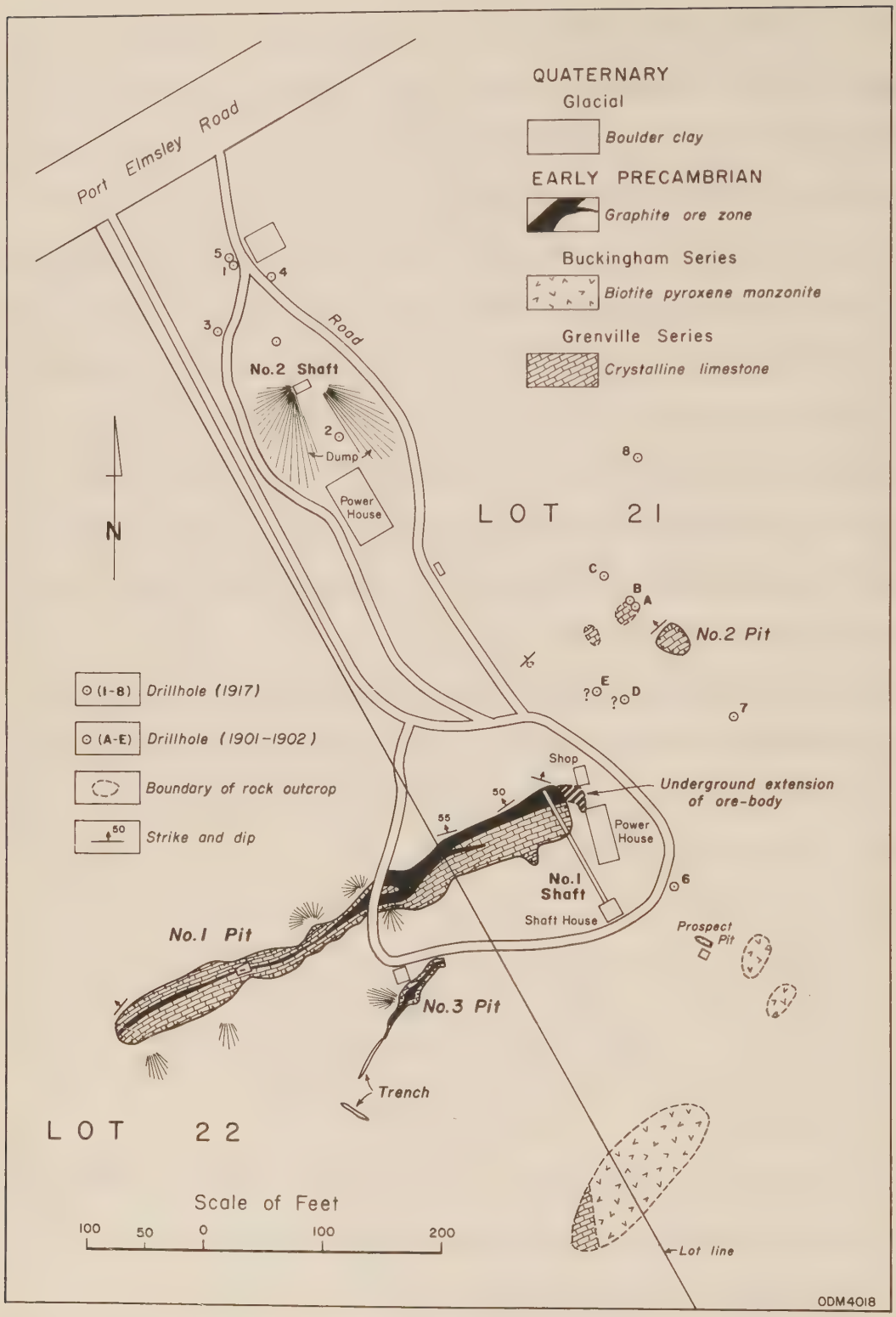

Figure 4. Globe Graphite mine, North Elmsley township, Lanark county. (Courtesy of Geological Survey of Canada).

property was examined and drilled by the Northern Graphite Company. In 1902 mining was begun by Rinaldo McConnell. Operations were suspended from 1903 to 1908 when the Globe Refining Company began operations. The mine ran until 1911. In October 1915 the mine was taken over by the Globe Graphite Mining and Refining Company and operated until 1919. It has been idle since.

The graphite occurs in silicated bands in white Grenville marble striking N.70°E. and dipping 50 to 60° northwest. The marble is intruded by pegmatite. The main ore zone which has been traced along strike for about 400 feet lies on the dragfolded north limb of an anticline. The Z-shaped dragfold pitches vertically. Spence (1920, p. 29) reports that the ore grade was 15 to 25 percent C. Diopside, feldspar, calcite, pyrite and titanite were the principal gangue minerals. The graphite ore occurs in three narrow bands separated by narrow graphite-poor marble bands. The maximum ore width on the crest of the dragfold was 40 feet.

Workings consist of the main pit 400 feet long trending N.65°E. Much of the ore came from this open pit which is 10 to 30 feet wide. A shaft was sunk at the northeast end of the pit to follow the ore to depth. Initially, the shaft was inclined at 60° to the northwest, but it became vertical with depth. The shaft was 250 feet deep with four levels at 100, 150, 200 and 250 feet. Levels extended approximately 200 feet in each direction along the ore strike.

No. 2 shaft was sunk to 106 feet at a point 400 feet northwest of the main shaft. Some drifting was done at 50 and 100 feet with little results.

A lengthy description of the mine is given by Wilson (1917, p. 29-42).

LEEDS COUNTY

Bastard Township

Concession I, Lot 10

Cornell Property

The Cornell graphite property of Portland Graphite Mines Limited is located on lot 10, concession I, Bastard township, Leeds county, on the farm of John J. Cornell, $3\frac{1}{2}$ miles northeast of the village of Portland on No. 15 highway. The farmhouse is $\frac{1}{2}$ mile north of the highway and the graphite zone is at the rear of the 200-acre farm about $\frac{1}{2}$ mile from the house.

The graphite occurs as disseminated flakes averaging about 1/8-inch in size in silicated Grenville marble and biotite paragneiss. The country rock Grenville marble and paragneiss strike N.50°E. and dip 60 to 80 degrees north. The metasediments are intruded by granite pegmatite. The graphite-bearing zone which has a width of 100 to 150 feet has been traced by trenching and stripping for a strike length of over

1,900 feet across the north end of the lot. The graphite zone outcrops on the south side of a low ridge in pasture-land. Initial development began in 1959. At the time of the writer's visit in 1962 the largest pit was at the north-east end of the zone and measured approximately 40 by 20 feet by 12 feet deep. Three chip samples taken by the writer across exposed zones of graphite ore averaged 12 to 15 percent C. Some narrow rich sections run as high as 50 percent C. The preliminary exploration indicates a lengthy and extensive zone of graphite-bearing paragneiss and marble.

Other graphite properties reported to have been investigated by the company are in lot 7, concession I, and lot 2, concession III, South Burgess township.

LENNOX AND ADDINGTON COUNTY

Ashby Township

Concession VIII, Lot 1

Graphite is reported to occur in lot 1, concession VIII, Ashby township, Lennox and Addington county (Spence 1920, p. 39).

Denbigh Township

Concession VIII, Lot 34

Graphite occurs as disseminated flakes and graphite

seams in white micaceous marble in lot 34, concession VIII, Denbigh township. The marble strikes N.42°E. and dips 66° N.W. It is intruded by white biotite syenite and pegmatite. An inclined shaft reported to be 50 deep feet deep has been sunk. Two pits, one measuring 55 by 15 feet, the other 18 by 8 feet and 6 to 9 feet deep are located near the shaft (Evans 1964, p. 33-34).

DISTRICT OF NIPISSING

Butt Township

Concession XI, Lot 8

A graphite occurrence just north of McGuire Lake in lot 8, concession XI, Butt township, District of Nipissing, was staked by D. J. Sheehan of Kearney in 1942. The property was optioned to Noranda Mines Ltd. and some surface work was done.

One pit examined measured 5 by 4 feet and 8 feet deep. There are strippings north and west of this pit. In the pit the rock is fine-grained, rusty-weathering, graphite-pyrite - quartz schist. The graphite flakes are small averaging 1/20 of an inch and make up 5 to 10 percent of the rock. Biotite and garnet are frequently present. The schistosity strikes north and dips 20°E.

DISTRICT OF PARRY SOUND

Chapman Township

Concession III, Lot 17

Some surface workings were put down on a graphite showing in lot 17, concession III, Chapman township, District of Parry Sound, by T. B. Tough in 1942. Strippings exposed a fine-grained, sugary, mica-poor graphite schist striking N. 60°E. and dipping 32°N.W. The graphite flake is very minute.

Concession III, Lot 18

Some stripping was done on a graphite showing in lot 18, concession III, Chapman township in 1942 by T. B. Tough, just south of Carmen (Hungry) Lake. Strippings exposed a 25-foot band of rusty biotite paragneiss carrying an estimated 10 percent graphite in flakes half a millimetre to one millimetre in diameter. The paragneiss strikes N.45°E. and dips 80°N.W. (Satterly 1943b,p. 63).

Concession IV, Lot 18

Rusty-weathering graphite-bearing paragneiss extends on to lot 18, concession IV, Chapman township, southeast of Carmen (Hungry) Lake. Some surface trenching and stripping was done by T. B. Tough in 1941 and 1942. The gneisses strike

N.10 to 35°E. and dip 60°N.W. Small graphite flake averaging ½ mm. in size makes up about 10 percent of the rock.

Laurier Township

Concession XIII, Lot 22

Graphite schist is exposed in some old pits north of Sausage Lake and south of a road from Trout Creek in lot 22, concession XIII, Laurier township. The graphite schist, which is interbanded with paragneiss, is 4 to 5 feet wide, strikes N.5°W. with a vertical dip. A grab sample assayed 28.66 percent carbon (Satterly 1943b, p. 63).

Lount Township

Concession II, Lot 25

Satterly (1956, p. 27) reports a showing of graphite-bearing syenite pegmatite cutting crystalline limestone about 150 feet south of the We-Na-Nak road in lot 25, concession II, Lount township. A shallow trench 50 feet long has been put down. Graphite flakes up to 1 inch across make up 10 percent of the syenite pegmatite over a width of 3 to 4 feet.

Spence Township

Concession XI, Lot 15

On lot 15, concession XI, Spence township a number of small test pits and strippings expose crystalline limestone with bands and inclusions of hornblende gneiss. The strippings were done in 1941 by T. B. Tough (Satterly 1943b, pp. 63-64).

Spence Township

Concession XIV, Lot 3

An occurrence of coarse graphite flakes in hornblende schist inclusions in crystalline limestone is described by Satterly (1943b, p. 64) in lot 3, concession XIV, Spence township. Some strippings were made on the property in 1941 by T. B. Tough.

PETERBOROUGH COUNTY

Anstruther Township

Concession I, Lot 38

An occurrence of graphite on lot 38, concession I, Anstruther township, Peterborough county, is described by Adams and Barlow (1910, p. 370). In 1890 a 35-foot shaft was sunk on a graphite-bearing granite pegmatite dike cutting crystalline limestone.

RENFREW COUNTY

Blithfield Township

Concession IV, Lots 13 and 14

A small occurrence of graphite has been reported near the bank of the Madawaska river in lots 13 and 14, concession IV, Blithfield township, Renfrew county. The graphite occurs in rusty paragneiss (Satterly 1945, pp. 42-3).

Concession V, Lot 25

An occurrence of graphite in paragneiss in lot 25, concession V, Blithfield township, Renfrew county, has been described by Satterly (1945, p. 43). A small pit has been put down on a 1-2 foot graphitic gneiss band interbedded with crystalline limestone.

Brougham Township

Concession III, Lot 16

A shaft 6 by 6 feet by 20 feet deep was put down by M. J. O'Brien in lot 16, concession III, Brougham township, in crystalline limestone. A few flakes of graphite are present in the limestone (Satterly 1945, p. 43).

Concession III, Lots 17 and 18

Black Donald Graphite Mine

The mine is located on the south shore of Black Donald (Whitefish) Lake on lots 17 and 18, concession III, Brougham township, Renfrew county. From its initial opening in 1896 until it was worked out in 1954, the Black Donald mine produced a total of 85,164 tons of graphite valued at $5,751,631, making it one of the most important producers of flake and amorphous graphite in Canada or the United States. This production represents 94 percent of the total value of Ontario graphite production.

The mine was opened in 1896 by the Ontario Graphite Company, who erected a mill on the property in 1902. In 1904 R. McConnell took over the operation and sunk the McConnell inclined and vertical shafts. In 1908, the Black Donald Graphite Company leased the property, and in 1909 overhauled and redesigned the mill. This company bought the mine in 1917 and continued underground operations until 1938, when the orebody was thought to be exhausted. Production continued from tailings. In 1941, the property was examined by Frobisher Limited and, in 1942, this company leased and later purchased the property. Frobisher Limited re-opened the mine, and operations from underground, surface and tailings recovery continued until 1954. Underground operations ceased in 1952.

The graphite ore zone forms a conformable bed within the Grenville marble - quartzite - paragneiss sequence. The country rocks consist of Grenville marble; silicated marble carrying

Black Donald Graphite mine

Black Donald Graphite mill

Figure 5. Plan of Black Donald mine, Brougham township, Renfrew county. (copied from a plan of the Frobisher Exploration Co. Ltd., July, 1942).

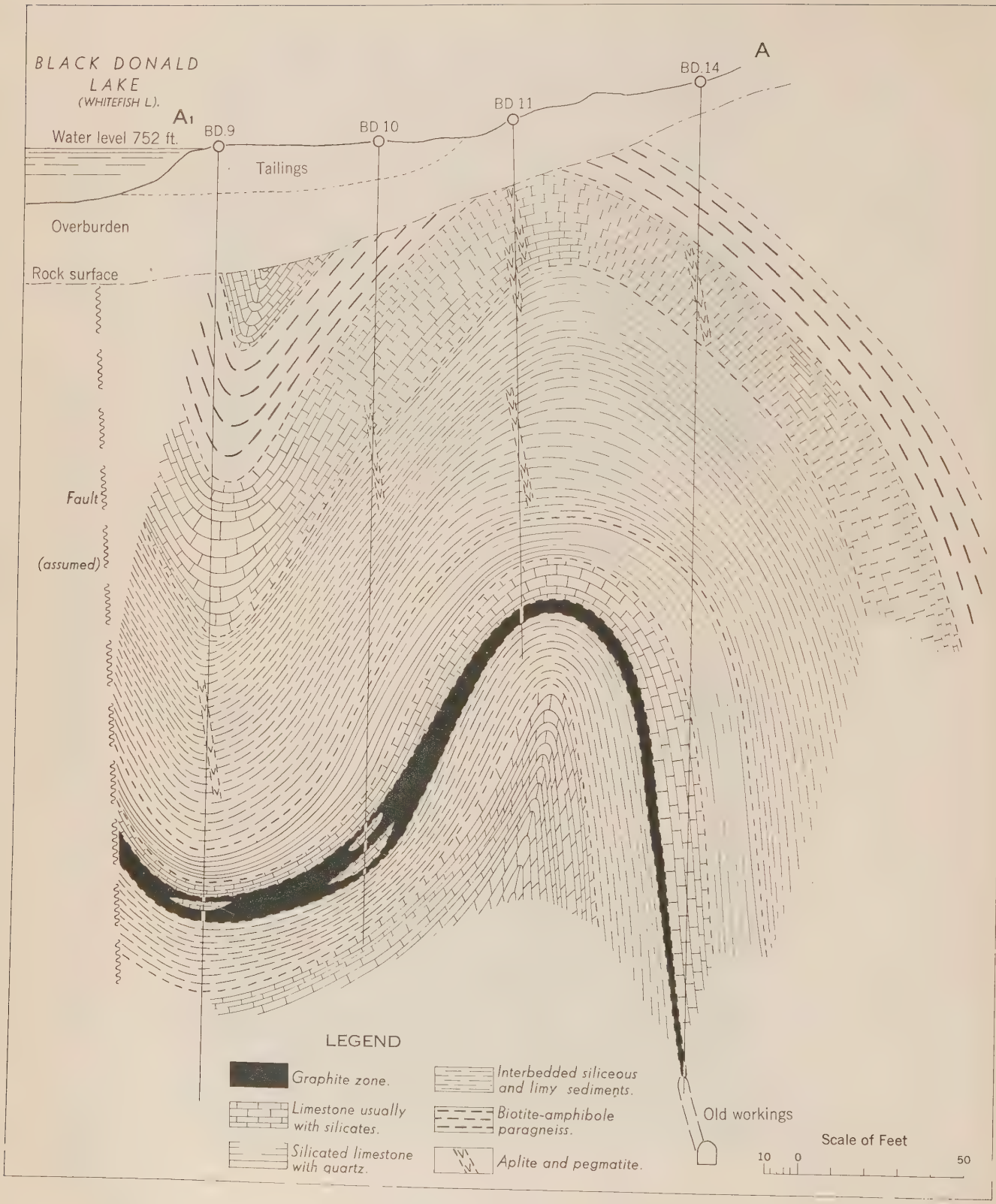

Figure 6. Vertical cross-section A-A1 Black Donald mine. (copied from a plan of the Frobisher Exploration Co. Ltd., July, 1942).

phlogopite, tremolite, scapolite and quartz; interbedded marble and limy quartzite; and paragneisses rich in biotite and hornblende. The Grenville quartzites are rich in pyrite and pyrrhotite, and weather rusty-brown. These Grenville rocks are cut by aplite and pegmatite dikes.

On surface the graphite ore zone at the Black Donald mine dips vertically, strikes northeast, and can be traced over a length of 800 feet. It had an average width of 20 feet, with a maximum width of about 70 feet at the northeast end. In 1920, H. S. Spence reported the average grade of the graphite ore at 65 percent, with some material locally ranging as high as 80 percent. The ore carries a large percentage of small flake graphite. During the last decade of its life the underground operations at the mine were carried out in ore grading from 25 - 30 percent graphite with about 15 percent of the product being flake. The chief impurity in the ore bed was calcite, with some lime silicates and chlorite.

As the workings were carried downward it was discovered that the ore bed was folded in a small dragfold with an amplitude of about 350 feet, as shown on the cross-section A-A' taken in a N.W. - S. E. direction across the ore zone near the south shaft. Here the ore bed is cut off on the west by a vertical fault. The stratigraphic sequence in the vicinity of the ore bed is shown in this cross-section. The ore is underlain by 15 - 20 feet of quartzite and limy quartzite, followed by beds of white or grey marble at least 200 feet thick. The ore zone is overlain by 15 - 40 feet of silicated marble carrying quartz, phlogopite, diopside, scapolite and tremolite. Overlying the marble is 50 - 60

feet of interbedded sandy marble and limy quartzite, followed by marble and paragneiss.

Section C-C' taken in a N.W.-S.E. direction across the orebody in the vicinity of the north (Ross) shaft indicates a much thicker bed of graphite ore in a very similar stratigraphic succession. The ore zone is cut off and displaced by a north-trending vertical fault and the intricate minor faulting and folding made detailed mapping difficult.

Underground mining was carried out over a length of about 1,000 feet. In section C-C' the ore zone is shown to be cut off on the southeast by a pegmatite dike. The dragfold structure plunges northeast at about 20°.

The most favourable zones within the orebody are along the limbs of the synclinal portion of the dragfold. The ore bed showed a pronounced zoning: in places there was a narrow footwall band of rich semi-amorphous ore, followed by "grey ore" of much lower grade, but containing a good percentage of flake. This was followed by the main band of rich semi-amorphous ore. The zoning is thought to be due to the variable composition of the replaced marble bed. The more permeable, easily replaced portions formed the richer semi-amorphous ore. The orebody is classed as metasomatic in origin, being the result of replacement of a marble bed by hydrothermal solutions perhaps originating from the same source as the pegmatite and aplite dikes, although these dikes appear in most cases to be post-ore.

That the graphite ore is secondary rather than primary is indicated in certain brecciated or "spotted dog" ore in which the relict brecciated structure of the original marble bed is preserved in the ore zone. The siliceous impermeable footwall of the

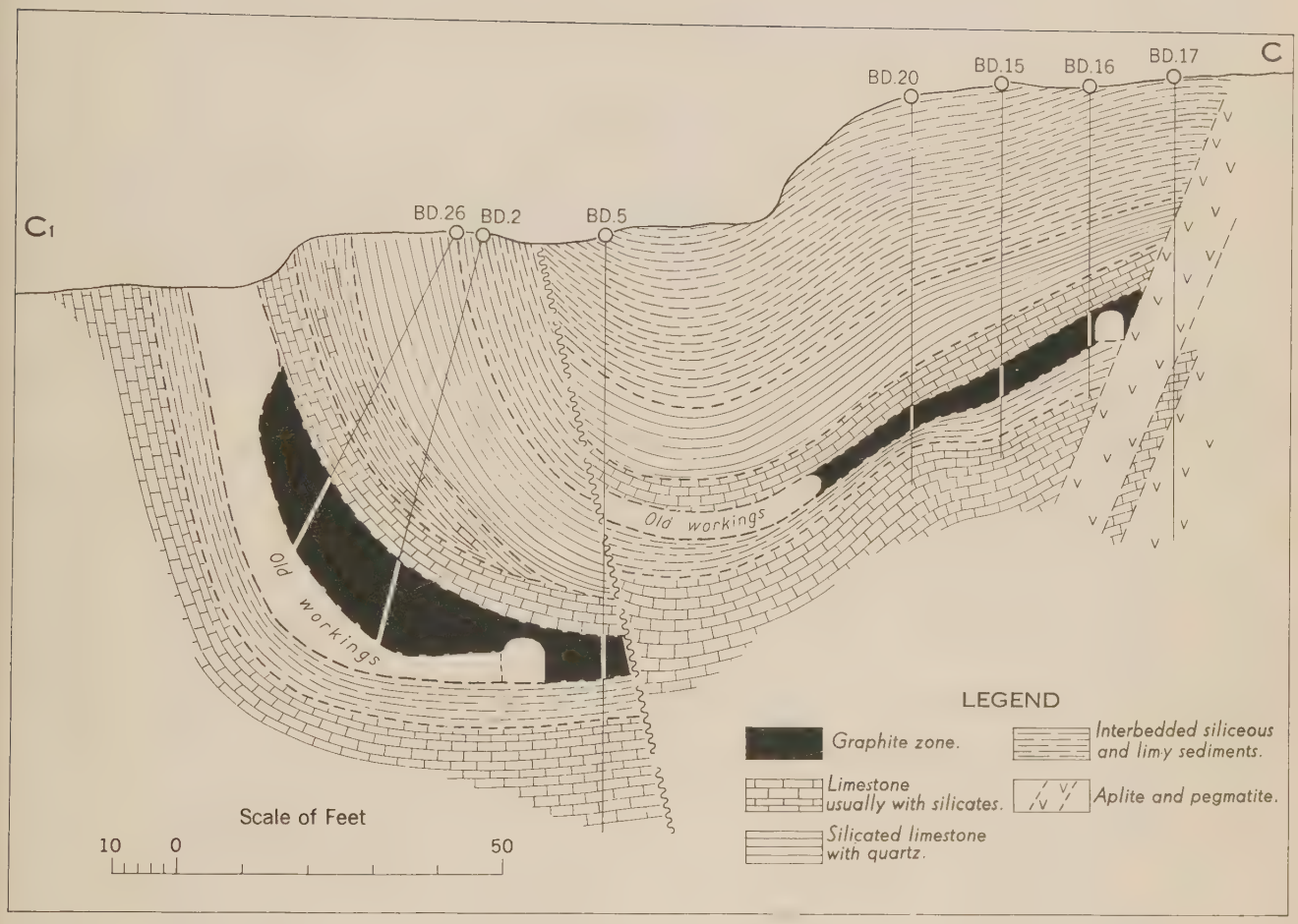

Figure 7. Vertical cross-section C-C_1 Black Donald mine. (copied from a plan of the Frobisher Exploration Co. Ltd., July, 1942).

ore zone and the overlying siliceous hanging-wall probably assisted in localizing the ore-forming solutions within the marble bed. The upper part of the marble bed is highly silicated and it is uncertain whether this silication occurred during the epoch of graphitization.

Milling

The flow sheet for the Black Donald mill in 1950 is given in the accompanying figure. The ore from the mine goes to a 20-ton bin. It is reduced to minus one inch size in a series of three consecutive jaw crushers and two screens. The crushed product is conveyed to a 150-ton mill storage bin.

The mill storage bin feeds the grinding circuit consisting of an Allis Chalmers ball mill in closed circuit with a trunnion trommel. The ball mill product is pumped to a Denver unit cell for removal of liberated flake prior to classification and secondary grinding. The classifier overflow is floated in a band of 6 Denver Sub-A flotation cells with the tailings therefrom going to waste. The rougher concentrate goes to a series of Callow cells to be cleaned four separate times. The tailings from the Callow cells are classified, reground, and returned to the rougher flotation circuit. The final flotation concentratesfrom the Callow cells go to a filter and drier and then to dry concentrate storage. The ultrafine portion is removed by a dust collector and is marketed as No. 40 and No. 50 smoke sizes.

The dried graphite concentrate is ground by 36-inch Munson mill stones following which a primary size separation is made between flake (coarse sizes) and amorphous (fine sizes). Products SR4, No.

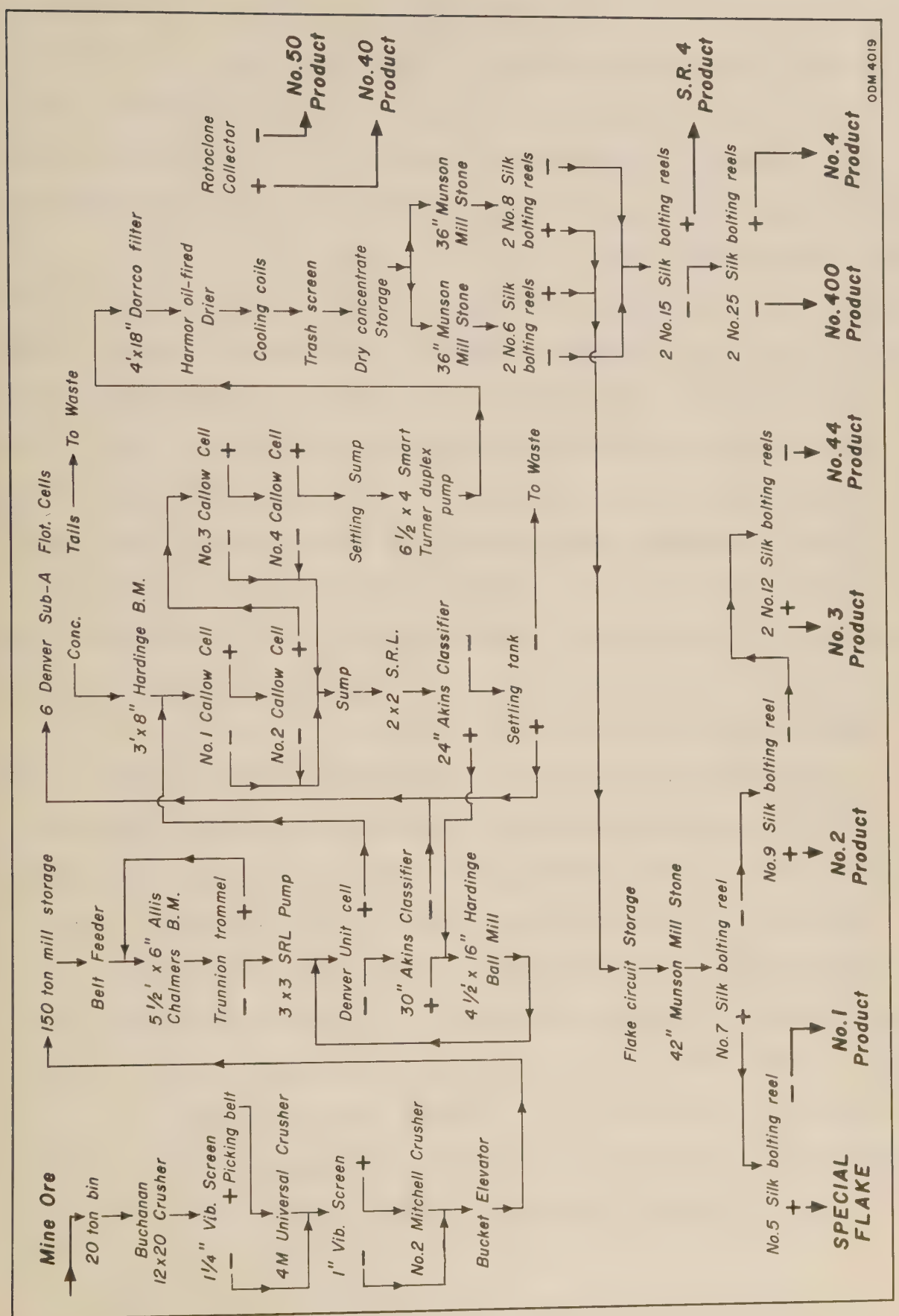

Fig. 8. Flow sheet, Black Donald mine.
(Courtesy of Frobisher Ltd., 1950.)

4 and No. 400 are amorphous sizes derived by subsequent screening of the finer fraction. Special, No. 1, No. 2, No. 3 and No. 44 are sized flake grades produced in a separate circuit by further grinding and screening operations. A dry grind ball mill (not shown) was also available to produce ground flake to particular customer specifications.

In general grade specifications depend upon the mesh, percent carbon, flakiness, feel and appearance. By way of example: grade No. 1 flake has the following average screen analysis: plus 30 mesh, 3.9 percent; plus 40 mesh, 32.4 percent; plus 50 mesh, 58.5 percent; plus 60 mesh, 4.1 percent; plus 80 mesh, 0.7 percent; minus 80 mesh, 0.4 percent. Minimum carbon content is 98.0 percent. SR 4 amorphous ran as follows on the average: plus 100 mesh, 23.6 percent; plus 150 mesh, 36.3 percent; plus 200 mesh, 24.0 percent; plus 325 mesh, 13.6 percent; minus 325 mesh, 2.5 percent. Carbon content ran 80 percent plus.

The grinding and flotation circuit was somewhat modified when described by Andersen (1954). He described it as follows: "From the bin, the ore is fed to the grinding circuit, consisting of a ball mill in closed circuit with a Dorr classifier. Water and the reagents required to effect the separation of the graphite from the gangue are added to the ball mill. The reagents used are: pine oil, kerosene, lime and sodium silicate. The first two named serve as a frother and a collector respectively. Though the ore itself is slightly alkaline, the lime is added whenever necessary to keep the pH of the pulp

between 9 and 10, the range which has been found to give the best recovery. The last reagent, sodium silicate, serves to suppress the quartz.

The overflow from the classifier goes to a Denver Sub A flotation machine where the graphite floats to the surface and is removed, while most of the gangue is discarded in the tailing. The rougher concentrate is passed over a vibrating screen which removes the plus 40 mesh material from the flotation circuit. This portion of the primary concentrate assays 80 percent C. or better and is sent directly to the filter. The 'unders' from the screen is subjected to further cleaning in a second Denver Sub A flotation machine, the tailing from which is returned to the classifier for regrinding. The final cleaning is accomplished in a Callow cell and the finished concentrate, together with the 'overs' from the vibrating screen, is sent to a vacuum filter, where most of the water is removed ahead of the drier. The tailing from the Callow cell is re-circulated in the second flotation machine. Average graphite assays during the past year of the feed, concentrate and tailings have been 15.0, 81.0 and 3.3 percent, respectively."

In 1949 the distribution of flake and amorphous products from the Black Donald mill were approximately as follows:

Flake	11.6 percent
Flake dust	30.8 "
Amorphous	55.7 "
Smoke	1.9 "

Prices of the products were approximately as follows in 1951:

		Price per pound in cents
Flake	No. 1	8.5
	No. 2	8.0
	No. 3	8.0
Flake dust	No. 44	4.0
	No. 888	4.5
Amorphous	No. 5	4.0
	No. 4X	6.5
Smoke	No. 50	5.0

The best grades of flake averaged over 98 percent carbon.

Concession VI, Lot 1

Graphite-bearing marble occurs in three pits in lot 1, concession VI, Brougham township. The graphite zones are reported to be small and lenticular (Satterly 1945, p. 47).

Concession VI, Lot 17

A graphite occurrence has been reported in lot 17, concession VI, Brougham township, about 500 feet south of the west end of Green Lake. Graphite flakes occur in a granular diopside rock interbedded with Grenville marble and mica schist but the deposit is reported to be small (Satterly 1945, p. 47-8).

Concession VIII, Lot 6

Disseminated graphite in scapolite gneiss at the contact of granite pegmatite and crystalline limestone is reported in lot 6, concession VIII, Brougham township. Two small pits have been put down on the deposit and a graphite zone 1½ feet wide is exposed (Satterly 1945, p. 48).

Concession X, Lot 13

Graphite flake occurs in white crystalline limestone in lot 13, concession X, Brougham township. A pit and trench have been put down near the west shore of Blake Lake. The graphite content is estimated at one percent (Satterly 1945, p. 48-9).

Griffith Township

Concession XIV, Lot 26

A graphite prospect on the north side of Cox Lake, in lot 26, concession XIV, Griffith township has been described by Satterly (1945, p. 49). A test pit 12 by 20 feet by 6 feet deep has been put down. A graphite-rich lens of ore running an estimated 30 percent carbon has a width of 6 to 24 inches. It is interbedded with hornblende gneiss which strikes N.50°E. and dips 35°S.E. The exposed length of the graphite lens is 8 feet.

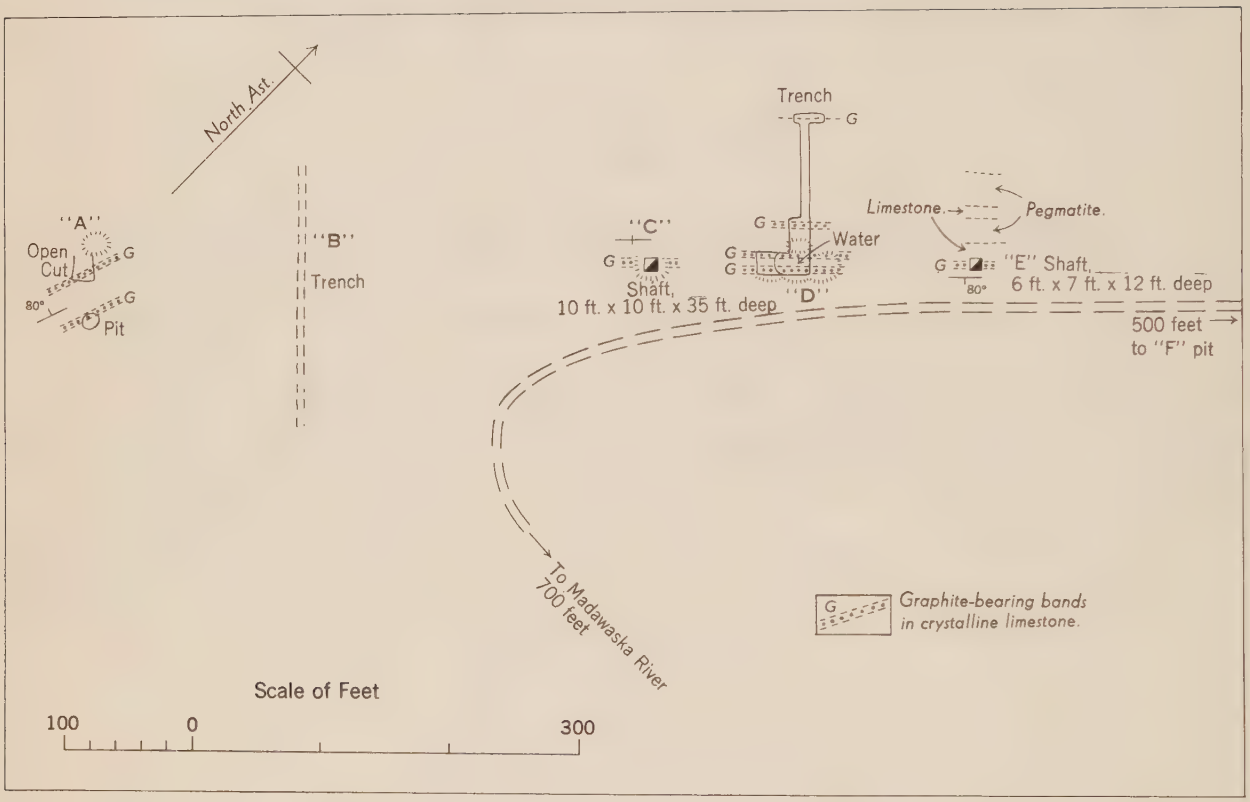

Figure 9. Sketch map of the graphite showings on lot 1, concession II, Lyndoch township, Renfrew county.

Lyndoch Township

Concession II, Lots 1 and 2

The graphite deposit on lots 1 and 2, concession II, Lyndoch township, is reported to have been discovered about 1880 by Dan Moriarty of Eganville. Most of the development work was done by Messrs. Beidelman and Lyall in 1917. The workings are located 700 feet north of the Madawaska river, just east of Mount Jamieson. They can be reached by wagon road running west from the road just west of the Highland Creek crossing.

The workings are described by Satterly (1945, pp. 49-51) as follows:

"In 1943 some of the workings were partly caved, overgrown, or filled with debris so that complete rock exposures were not available for examination. Six workings, in a general northeast-southwest direction, at intervals over a length of 1,900 feet, were seen (see Fig. 9). In these workings the graphite occurs as disseminated flakes in narrow bands in white crystalline limestone. Phlogopite is usually present along with the graphite.

At the southwest end at "A", an open cut and pit expose several bands of graphite. The open cut is 15 by 20 feet with a 6-foot face. It exposes a zone of graphite-bearing limestone, which is 5 feet in width, strikes N.20°E., and dips 80°W. The graphite flakes are mainly from a twentieth to a tenth of an inch in diameter, but are occasionally as wide

as a quarter of an inch. The graphite content across the 5 feet is estimated at 20 percent. A small pit, 25 feet to the southeast of the open cut, exposes a number of narrow graphite-bearing bands alternating with barren bands across a total width of 5 feet. The graphite content across the 5 feet is estimated at less than 10 percent.

Trench "B" is now largely caved in, and little can be seen. A little graphite was observed at one place.

Shaft "C", which is 10 by 10 feet and 35 feet deep, is surrounded by broken rock except at its northwest side. The banding in the limestone strikes N.45°E., and the dip is vertical. Material on the dump shows that the graphite-bearing bands in the crystalline limestone range from a mere row of flakes to bands 2 inches in width, and larger blocks indicate that some bands may be 4 inches wide. Phlogopite is nearly always present with the graphite. The barren limestone between the bands consists of a coarsely crystalline calcite. The amount of graphite ranges from less than 1 up to 20 percent, and may average 5 percent. The width of the graphite zone in the shaft could not be observed.

Trench "D" is irregular in shape. There is water in its southern part, and much debris or waste rock in other places. Four graphite-bearing zones were seen here. In the southeastern part two zones are 3 and 4 feet wide. At the extreme northwest end there is very little graphite. The zones may average 10 percent graphite. As before, the graphite occurs disseminated in bands as much as an inch or more in width with barren coarse

calcite between. Some much higher grade material (50 percent) was found on the dump, but none could be seen in place. Freeman (1936, p. 21) reports that near the centre of the zone bands from $1\frac{1}{2}$ to 2 feet wide contain over 50 percent flake graphite.

A shallow shaft, "E", 6 by 7 feet and 12 feet deep, exposes a 6-foot zone of disseminated graphite containing a 1-foot barren zone in the middle. On the northwest wall of the shaft a shear zone accounts for a rich band of graphite, from 3 to 4 inches wide. To the northwest of the shaft two pegmatite sills (?), 18 and 25 feet wide, intrude crystalline limestone containing less than 1 percent graphite.

A pit, "F", 8 by 10 feet and from 3 to 6 feet deep at 1,225 feet northeast of shaft "E" exposes a low-grade 1-foot graphite zone in crystalline limestone.

The work to date, consisting of pits, trenches, and shafts at intervals over a length of 1,900 feet, has indicated the presence of a number of graphite-bearing zones in and parallel to the bedding of a crystalline limestone trending northeast and southwest. It is not certain that these zones are continuous. The grade of the zones and type of occurrence are such that further exploration may be warranted in order to prove the size and grade of the deposit as a whole. "

Concession XV, Lot 24

At the south end of lot 24, concession XV, Lyndoch township, $\frac{1}{4}$ mile south of the Letterkenny road, a small prospect pit, 6 by 8 feet, has been driven into the north face of a

small knoll. The pit is in graphitic marble. Flakes of graphite up to 1/8-inch in size make up 5 to 10 percent of the rock in the richer bands. The silicated graphitic marble is interbedded with paragneiss. The graphite-bearing bands range from a few inches to 2 feet in width.

Ross Township

Concession X, Lot 9

A minor graphite occurrence is reported by Satterly (1945, p. 51) in lot 9, concession X, Ross township. Graphite marble is exposed in a 3 by 3 by 3-foot prospect pit.

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